

LES and RANS Model Evaluations of Flow Around a Complex Building

R. Calhoun, S. Chan, R. Lee, J. Leone, J. Shinn and D. Stevens

*This article was submitted to
3rd Symposium on the Urban Environment
Davis, CA
August 14-18, 2000*

U.S. Department of Energy

Lawrence
Livermore
National
Laboratory

June 2, 2000

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6.4 LES AND RANS MODEL EVALUATIONS OF FLOW AROUND A COMPLEX BUILDING

Ronald Calhoun*, Stevens Chan, Robert Lee, John Leone, Joe Shinn, David Stevens
Atmospheric Science Division
Lawrence Livermore National Laboratory, Livermore, CA 94551

1. INTRODUCTION

We compare the results of computer simulated flow fields around a complex building (B170) at Lawrence Livermore National Laboratory (LLNL) with field measurements (see Shinn 2000, this proceedings). This is the first stage of a larger effort to assess the ability of computational fluid dynamics (CFD) models to predict atmospheric dispersion scenarios around building complexes. At this stage, the focus is on accurate simulation of the velocity field. Two types of simulations were performed: predictive and post-experiment. The purpose of the predictive runs was primarily to provide initial guidance for the planning of the experiment. By developing an approximate understanding of the major features of the flow field, we were able to more effectively deploy the sensors.

The post-experiment runs were performed for several reasons: 1) The largest amount of experimental data was available for slightly different wind directions than the directions used in the initial calculations. The predictive runs simulated three wind directions: 200, 225, and 250 degrees measured from true north. Although, the winds did blow generally from the southwest (typical summer conditions for this site), the most appropriate data available was for 210, 225, and 240 degrees. 2) We wanted to explore the sensitivity of the predictions to various levels of idealization that are by necessity a part of the modeling process. For example, what level of detail is required to accurately model the effect of the trees? How much architectural detail should be included in the model of the building? (Figure 1 shows the most detailed level of idealization of the building.) 3) We are testing the sensitivity of the results to different turbulence closures.

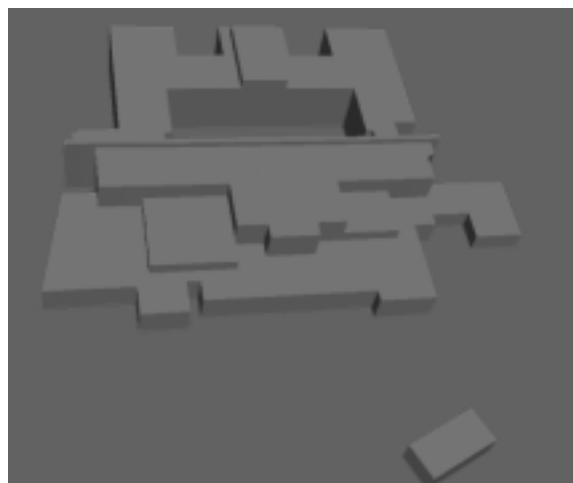


Figure 1. Geometry of building – note the multi-levels, courtyard, alcoves, architectural fin, and building extension to the right.

2. MODELING APPROACH

The numerical model used in this study is an extension of a finite element model used to simulate heavy-gas dispersion (Chan, 1994; Gresho and Chan, 1990). The model integrates the time-dependent, incompressible Navier-Stokes equations and uses boundary-fitted meshes combined with an ability to mark specified cells as ‘solid’ (i.e., useful for detailed resolution of flow domains which include buildings). The modeling framework has been improved using an object-oriented approach with message passing, as discussed in Stevens, et al. 2000. We have performed planetary boundary layer simulations with this framework with up to 40 million gridpoints. We use a number of different turbulence closures; a K-theory model (Reynolds Averaged Navier Stokes [RANS]), buoyancy-extended k-epsilon, (RANS), a nonlinear eddy viscosity model (RANS), and Large-Eddy Simulation (LES) model. At this stage of the project, we are using a simple Smagorinsky approach for our LES turbulence closure.

*Corresponding author address: Ronald J. Calhoun,
LLNL (L-103), P.O. Box 808, Livermore, CA
94551.
email: calhoun7@llnl.gov

3. SAMPLE RESULTS

We have compared model versus experimental mean wind vectors for a number of different wind directions. Results for 210 degrees are presented in Figure 2. The model solution generally captures the mean dynamics of the flow field. The experiment has illuminated several areas where the model solution might be improved. Especially challenging are regions of the flow where large velocities are near small recirculations; although in these cases, uncertainty in the location of the sensors may be partially responsible for discrepancies. In addition, perturbations (caused by the building) in the angle of the vectors (relative to ambient winds) tend to attenuate more rapidly away from the building than the model predicts. Numerical metrics (see Calhoun et al. 1999) corroborate the impressions gained by inspection of the vector fields; i.e., that most of the discrepancies between the modeled and experimental wind fields are small relative to the ambient winds. Time dependent features of the flow are being investigated using an LES approach (see Figure 3). Preliminary runs suggest that winds from the southwest flowing past the northwest corner of the building trigger strong turbulence and mixing near the north side of the building.

When considering the inherent level of uncertainty in atmospheric flows of this kind, the overall agreement between the modeled and experimental fields is remarkable. Accurately capturing the dynamics is a key first step towards better understanding dispersion scenarios. The next step is to evaluate which aspects of the flow field are most important for dispersion, and therefore which errors should be most strongly minimized.

Acknowledgments: This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-Eng-48.

7. REFERENCES

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Figure 2. Comparison of modeled and experimental wind vectors for ambient winds of 210 degrees.

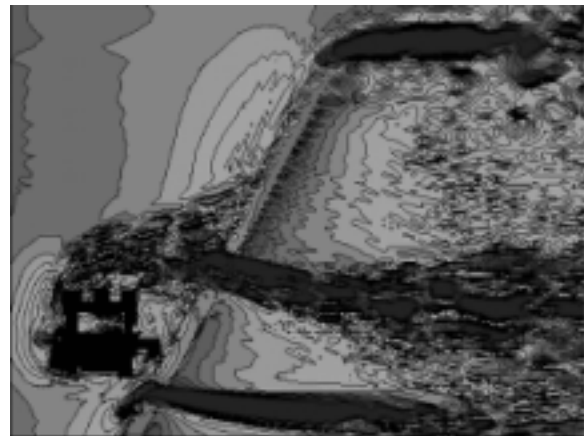


Figure 3. Contours of U-velocity (along horizontal axis) for LES with ambient winds at 225 degrees.